

# ***U.S. PATENT APPLICATION***

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***Invention:*** UNDERWATER BUILDING UNIT AND METHODS OF INSTALLATION  
AND APPLICATION THEREOF

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## ***SPECIFICATION***

# **Underwater Building Unit and Methods of Installation and Application Thereof**

## **Technical Field:**

The present invention relates to an underwater building unit and its installation and application methods.

## **Background of the Invention:**

At present, normally the construction of underwater permanent building, such as sea entry road and artificial island, is to fill grit into water first until higher than water level, and then to construct slope protection dam, i.e. artificial island with slope protected by sand bag, artificial island with natural slope and artificial island at the expense of beach. By this method, the amount of grit used increases in geometric order with water depth. It costs much and has short life. Another method is to fill the square-shaped caisson with grit, solidified soil in bags, or concrete which does not spread in water and then to heighten it with cast-in-place concrete with mould plate after it is higher than water level. Because the two boxes of square-shaped caisson are repeated and there is no stake foundation, it is easy to be destroyed by stormy waves. The disadvantage of this method lies in: not only the seabed foundation needs to be disposed during construction, but also the hoisting of the caisson is too frequent when the caisson is small, and inconvenient when the caisson is too big and heavy. Accordingly, this method takes long construction period and high cost while safety factor is low.

## **Summary of the Invention:**

The object of this invention is to provide an underwater building unit featured by simple structure, low cost, firm, easy to install and no need of disposal for seabed etc., and its application method.

The building unit of this invention is mainly an open caisson, includes a caisson with both ends open and is composed of two rows of box boards not

being intersected with each other; each row of box boards consists of a set of stake-plate body combinations and bind members between every two adjacent stake-plate body combinations; a positioning beam is located on the top of the box boards and connects the two box boards; and a cross rib is at the middle section of the outer surface of the plate body of each bind member. The open caisson of this invention is made up of small components with low weight. So it is easy for installation and could be extended unlimitedly as required. In addition, the open caisson with stake make it have low underwater condition requirement and be relatively stable, thus the underwater building is quite firm and has a long life. Each component of this open caisson can be industrially manufactured on land so as to lower the cost and free of the influence of stormy waves. Specifically, taking weight and cost into consideration, there are two forms of open caisson which can be applied to shallow water and deep water construction areas respectively. The structure of the open caisson which applies to the shallow water area is described as follows: the said bind members are positioning stake-plate body combinations which are located above the cross rib of the plate body and have outwardly protruded parts, stake-plate body combination and positioning stake-plate body combination are mounted facing each other in two rows of box boards respectively; positioning beam mounting groove is formed in the middle of the top edge of the plate body of the positioning stake-plate body combination, at least a part of the main girder of the positioning beam is embedded into the positioning beam mounting groove; and the length of the main girder of the positioning beam should be consistent with the distance between the outer edges of the plate bodies of the two opposite positioning stake-plate body combinations of two rows of box boards. In the above structure, a cross rib is provided on the outer surface of the stake-plate body combination, is located at the position being consistent with the cross rib on the plate body of the positioning stake-plate body combination, and is coupled with the outwardly protruded parts of the plate body of the positioning

stake-plate body combination. The length of the cross rib should let the rib to be coupled with the protruded part on top of the positioning stake-plate body combination and the width of the cross rib should be greater than the width of the plate body of the positioning stake-plate body combination. The structure of the open caisson which applies to the deep water area is described as follows: the stake-plate body combination in two box boards is positioned in pairs and facing each other, the said bind member is a positioning baffle comprised of a plate body and an outward lug protruded outwardly along the direction of its outer surface on the upper edge of the plate body; and a groove is provided on the lower surface of the positioning plate body at the two ends of the positioning beam to be coupled with the upper part of the middle stake of the stake-plate body combination, the length of the main girder of the positioning beam should be consistent with the distance between the outer edges of the plate bodies of the two opposite positioning stake-plate body combinations of two rows of box boards. In the above structure, the cross rib on the positioning baffle is composed of at least one cross rib connecting the two vertical ribs at the middle part of the positioning baffle.

A wall can be built on top of the open caisson for both structures stated above. The wall is formed by connecting the plate body-plate body combination which is composed of two plate bodies posed at an angle and the connecting plate body between the two plate bodies, a space is provided between the upper and the lower end surfaces of the plate body-plate body combination and the plate body for the cast-in-place concrete. Also, reinforcing bar through holes are preferably formed on the connecting plate body, in which reinforcing bars connecting the plate body-plate body combination passes through the plate body-plate body combination to have plate body-plate body combination positioned. The plate body-plate body combination can have the following shapes: the upper and the lower end surfaces of the connecting plate body is perpendicular to one of the plate bodies. The connecting plate body is integrally

formed as a single unit with one of the plate body, a corresponding mounting hole is formed on the other plate body, pre-buried reinforcing bars are placed inside the hole, and protruded pre-buried reinforcing bars are provided on the end surface on which the connecting plate body is connected with the plate body.

Additionally, a breakwater is provided above the plate body-plate body combination.

The installation method of the open caisson for this invention when used in shallow water areas is as follows:

- a. locate the insert plate centring frame on water bottom along design direction;
- b. put the two rows of stake-plate body combination to a predetermined depth according to the position mark of the centring frame above water surface and set in place;
- c. hang the positioning frame away;
- d. for each row of stake-plate body combination, put positioning stake-plate body combination into the preserved gaps between every two adjacent stake-plate body combinations and make the outward protruded positioning part lock the stake-plate body combination and positioned by a cross rib; and
- e. locate the no-ear positioning beam in the open groove of the positioning stake-plate body combination.

The installation method of the open caisson for this invention when used at deep water areas is as follows:

- a. locate the insert plate centring frame on water bottom along design direction;
- b. put two rows of stake-plate body combination to a predetermined depth according to the position mark of the centring frame above water surface and set in place;

- c. hang the insert plate centring frame away;
- d. make positioning beam with forked ear buckled on two stake-plate body combinations to make the opening of the positioning beam baffle and the stake of the stake-plate body combinations being lock by each other; and
- e. for each row of stake-plate body combination, put the positioning baffle with rib in the space between two adjacent stake-plate body combinations to make the upper outwardly protruded lug to be located on top of the stake-plate body combination.

For the above two cases, in case the foundation is too soft, when inserting the stake-plate body combination or the positioning stake-plate body combination, the stake is put into foundation to a predetermined depth first and filled with grit or crushed stone through the stake holes, then is lifted to make the filling material spread into the gap around the tip of the stake and then put back in.

The construction of the sea entry road is proceeded as follows:

- a. put the open caisson into water;
- b. make the open caisson full of rubble;
- c. add rubble to design height;
- d. place mould plate above two rows of structural members of the open caisson; and
- e. cast-in-place concrete between the mould plates to design height.

The construction of the artificial island is proceeded as follows:

- a. put the open caisson into water and form an annular frame;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination on top of the open caisson;
- d. put the trunk reinforcing bar through the reinforcing bar through hole in the plate body-plate body combination and tie up the trunk reinforcing bars with hoops;
- e. cast-in-place concrete in the plate body-plate body combination and

- preserve space for breakwater;
- f. install the breakwater at the preserved space; and
- g. fill the inside of the annular wall formed by the plate body-plate body combinations and the breakwater with dry soil until reaching the height of the wall.

The construction of the seawall is proceeded as follows:

- a. put the open caisson into water along design direction;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination on top of the open caisson;
- d. put the trunk reinforcing bar through the reinforcing bar through hole on the plate body-plate body combination and tie up the trunk reinforcing bars with hoops;
- e. cast-in-place concrete in the plate body-plate body combination and preserve space for the breakwater;
- f. install the breakwater at preserved space; and
- g. fill the inside of the downstream face of the wall formed by the plate body-plate body combination and the breakwater with dry soil until reaching the height of the wall.

#### **Brief Description of the Drawings:**

Fig. 1 is a front view of Embodiment 1;

Fig. 2 is a vertical view of Fig. 1;

Fig. 3 is a left view of Fig. 1;

Fig. 4 is a front view of the stake-plate body combination of Figs. 1-3;

Fig. 5 is a left view of Fig. 4;

Fig. 6 is a vertical view of Fig. 4;

Fig. 7 is a front view of the positioning stake-plate body combination;

Fig. 8 is a left view of Fig. 7;

Fig. 9 is a vertical view of Fig. 7;

Fig. 10 is a sectional view of the sea entry road in the shallow water area;

Fig. 11 is a sectional view of Embodiment 2;  
Fig. 12 is a front view of the plate body-plate body combination;  
Fig. 13 is a right view of the plate body-plate body combination;  
Fig. 14 is a front view of Embodiment 3;  
Fig. 15 is a vertical view of Fig. 14;  
Fig. 16 is a left view of Fig. 14;  
Fig. 17 is a front view of the positioning baffle;  
Fig. 18 is a left view of Fig. 17;  
Fig. 19 is a upward view of Fig. 17;  
Fig. 20 is a sectional view of the sea entry road in deep water area; and  
Fig. 21 is a sectional view of Embodiment 4.

Wherein, the reference numerals refer to:

- 1-positioning stake-plate body combination
- 2-stake-plate body combination
- 3-positioning beam
- 4- and 5-cross ribs
- 6-breakwater
- 7-plate body-plate body combination
- 8-connecting plate body
- 9-reinforcing bar through hole
- 10-reinforcing bar
- 11-stake-plate body combination
- 12-positioning baffle
- 13-positioning beam
- 14-outward lug
- 15-cross rib
- 16-vertical rib

#### **Detailed Description of the Preferred Embodiments:**

Embodiment 1:



In this embodiment, an open caisson is used in shallow water area. It consisted of two box boards composed of two rows of stake-plate body combination 2 and the positioning stake-plate body combination 1 which were disposed facing each other and the positioning beam 3 above the two box boards. Cross ribs 4 and 5 were located at the outer surface of the plate body of each of the stake-plate body combination 2 and the positioning stake-plate body combination 1. Both the upper and the middle parts of the outer surface of the stake-plate body combination 2 had cross rib 4. There were protruded parts on two sides of the plate bodies above the cross rib of the positioning stake-plate body combination 1. The stake-plate body combination 2 and the positioning stake-plate body combination 1 of each row of the box board were installed alternately. The distance between the two adjacent stake-plate body combinations 2 was consistent with the width of the plate body of the positioning stake-plate body combination 1. The positioning stake-plate body combination 1 was located at the outside of the stake-plate body combination 2 during installation and the protruded parts at the two sides above the positioning stake-plate body combination 1 was located above the middle cross rib of the stake-plate body combination 2. In this embodiment there was a positioning beam mounting groove on the middle part of the upper end surface of the plate body of the positioning stake-plate body combination 1. The length of the main girder of the positioning beam was consistent with the distance between the outer surface of the plate bodies of the two opposite positioning stake-plate body combinations (1) of two rows of box boards. The positioning beam 3 was embedded in the groove on the upper end surface. The positioning plate bodies at two sides of the positioning beam 3 were located at the outside of the positioning stake-plate body combination 1.

During construction, the insert plate centring frame was placed on water bottom along design direction first and two rows of stake-plate body combination 2 was put to a predetermined depth according to the position mark

of the centring frame above water surface through gravity vibration or the press of the scoop of the excavator or flushing and set in place. In case the foundation was too soft and the stake could not stand up, the stake hole should be filled with grit or crushed stone and local disposal was conducted for the foundation of the stake tip, then the positioning frame was hanged away. For each row of the stake-plate body combination 2, the positioning stake-plate body combination was put into the preserved gaps between every two adjacent stake-plate body combinations 2 and the outwardly protruded positioning part was made to lock the stake-plate body combination 2 and positioned by a cross rib 4. The no-ear positioning beam 3 was located in the open groove of the positioning stake-plate body combination 1.

The construction of the sea entry road was proceeded as follows:

- a. put the open caisson into water;
- b. make the open caisson full of rubble;
- c. add rubble to design height;
- d. place the mould plate above two rows of structural members of the open caisson; and
- e. cast-in-place concrete between the mould plates to design height.

#### Embodiment 2:

In this embodiment, an open caisson was used in shallow water area, the plate body-plate body combination 7 and the breakwater 6 were provided on the open caisson. The structure of the open caisson used in shallow water area was the same as that in Embodiment 1 and will not be restated here. The plate body-plate body combination 7 in this embodiment was composed of two plate bodies posed at an angle and the connecting plate body 8 between the two plate bodies. The connecting plate body 8 was perpendicular to one of the plate bodies and was integrally formed as a single unit with one of the plate body. A corresponding mounting hole was formed on the other plate body, pre-buried reinforcing bars were placed inside the hole, and protruded pre-buried

reinforcing bars were provided on the end surface on which connecting plate body was connected with the plate body. The outside end of the connecting plate body 8 was embedded in the mounting hole. Reinforcing bar through holes 9 were formed on the connecting plate body 8, reinforcing bars connecting the plate body-plate body combination past through the reinforcing bar through holes 9. A space was provided between the upper and the lower end surfaces of the plate body-plate body combination and the plate body for the cast-in-place concrete. The breakwater is available in the prior art.

During installation, a row of plate body-plate body combination 7 was placed above the open caisson first and reinforcing bars were made pass through the reinforcing bar through hole 9 on the connecting plate body 8. Concrete was cast into the plate body-plate body combination 7 and the breakwater 6 was installed above the plate body-plate body combination 7.

When building artificial island with this kind of open caisson, the procedure was as follows:

- a. put the open caisson into water and form an annular frame;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination above open caisson;
- d. pass the trunk reinforcing bar through the reinforcing bar through hole in plate body-plate body combination and tie up trunk reinforcing bar with hoop;
- e. cast-in-place concrete within the plate body-plate body combination and preserve space for the breakwater;
- f. install the breakwater at the preserved space; and
- g. fill the inside of the annular wall shaped by plate body-plate body combination and breakwater with dry soil until reaching the height of wall.

When building seawall with this kind of open caisson, the procedure was as follows:

- a. put the open caisson into water;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination on top of the open caisson;
- d. put the trunk reinforcing bar through the reinforcing bar through hole on the plate body-plate body combination and tie up the trunk reinforcing bars with hoops;
- e. cast-in-place concrete in the plate body-plate body combination and preserve space for the breakwater;
- f. install the breakwater at the preserved space; and
- g. fill the inside of the annular wall body formed by the plate body-plate body combination and the breakwater with dry soil until reaching the height of the wall body.

#### Embodiment 3:

In this embodiment, an open caisson was used in deep water area. It consisted of two box boards composed of two rows of stake-plate body combination 11 and the positioning stake-plate body combination 12 which were disposed facing each other and the positioning beam 13 above the two box boards. The stake-plate body combination 11 in this embodiment consisted of plate bodies and stakes, the positioning baffle 12 is comprised of a plate body and an outward lug protruded outwardly along the direction of its outer surface on the upper edge of the plate body. There are two vertical ribs 16 in the middle of the outer surface of the plate body, two cross ribs 15 was provided between the two vertical ribs 16 and connected the two vertical ribs 16. The stake-plate body combination 11 and the positioning baffle 12 in each row of the box boards are installed alternately. The positioning baffle 12 was located between two adjacent stake-plate body combinations 11. Two sides of the positioning baffle 12 and the inside surface of the stake-plate body combination 11 overlapped with each other. The outward lug 14 was located above the stake-plate body combination 11. In this embodiment there was a positioning plate body with an open groove

at two ends, the lower end surface of the main girder of the positioning beam 13. The length of the main girder of the positioning beam was consistent with the distance between the two opposite positioning stake-plate body combinations 11 of two rows of box boards.

The installation method of this open caisson used in deep water area was as follows: locate the insert plate centring frame on water bottom along design direction; put two rows of stake-plate body combination to a predetermined depth according to the position mark of the centring frame above water surface and set in place using a corresponding method as used in shallow water area; hang the insert plate centring frame away; make positioning beam 13 with forked ear buckled on two stake-plate body combinations 11 to make the opening of the baffle of the positioning beam 13 and the stake of the stake-plate body combination 11 being lock by each other; and for each row of stake-plate body combination 11, put the positioning baffle 12 with rib in the space between two adjacent stake-plate body combinations 11, let the upper part of the outward lug 14 sit on the top of the plate body of the stake-plate body combination 11.

When building sea entry road with this kind of open caisson, the procedure is as follows:

- a. put the open caisson into water;
- a. make the open caisson full of rubble;
- b. add rubble to design height;
- c. place mould plate above two rows of open caisson unit; and
- d. cast-in-place concrete among mould plate to design height.

#### Embodiment 4:

In this embodiment, the open caisson for deep water area, the plate body-plate body combination 7 and the breakwater 6 on the plate body-plate body combination 7 were used. The structure of the open caisson is the same as that in Embodiment 3 and the structure of the plate body-plate body combination 7

and the breakwater 6 is the same as that in Embodiment 2. They were in turn installed on top of the open caisson. This will not repeat here.

The installation method of the open caisson in this embodiment is the same as that in Embodiment 3. The installation method of the plate body-plate body combination 7 and the breakwater 6 is the same as that in Embodiment 2.

When building an artificial island with this open caisson, the procedure is as follows:

- a. put the open caisson into water and form an annular frame;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination on top of the open caisson;
- d. put the trunk reinforcing bar through the reinforcing bar through hole in the plate body-plate body combination and tie up the trunk reinforcing bars with hoops;
- e. cast-in-place concrete in the plate body-plate body combination and preserve space for the breakwater;
- f. install the breakwater at the preserved space; and
- g. fill the inside of the annular wall formed by the plate body-plate body combinations and the breakwater with dry soil until reaching the height of the wall.

When build seawall with this kind of open caisson, the procedure is as follows:

- a. put the open caisson into water along design direction;
- b. make the open caisson full of rubble;
- c. install the plate body-plate body combination on top of the open caisson;
- d. put the trunk reinforcing bar through the reinforcing bar through hole on the plate body-plate body combination and tie up the trunk reinforcing bars with hoops;
- e. cast-in-place concrete in the plate body-plate body combination and

preserve space for the breakwater;

- f. install the breakwater at the preserved space; and
- g. fill the inside of the downstream face of the wall formed by the plate body-plate body combination and the breakwater with dry soil until reaching the height of the wall body.